Seamanship

Wave Theory and Practice, Part II

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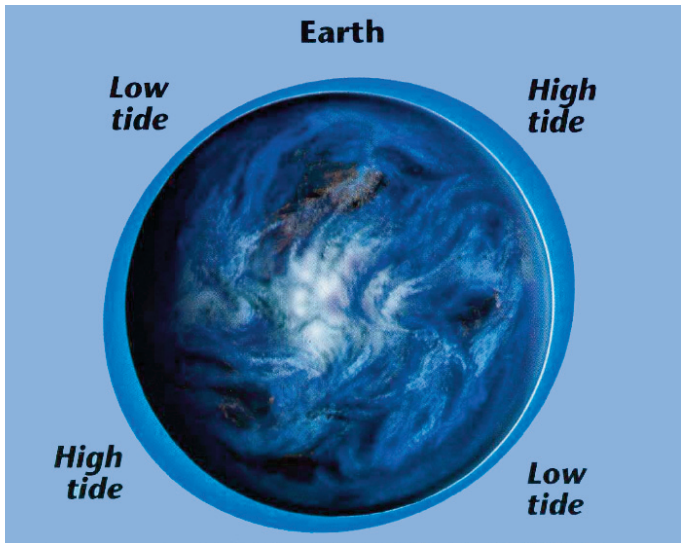
When we first put together the column on waves (see LIBW, "**Cat's Paws to Grey Beards: Wave Theory – and Practice"**, September 2011), I noted that we'd get back to waves and talk about different kinds of waves - tsunamis, deep, shallow, non-wind, etc – and the effect they have on mariners. This column completes that promise.

Wind Creates Waves

Almost always, this is true. Almost. There are what scientists call "non-wind" waves; the two most common are the tides and tsunamis. Back in September I closed the column by noting that the longest wave on the planet was, in fact, that wave created by the moon, lifting the water up and dragging it around the Earth. The closing question was "what is the frequency?" The frequency of the tidal wave (not to be confused with a tsunami, often called a tidal wave) created by the rotation of the moon around the Earth is about 12 ½ hours. The wavelength is half of the circumference of the Earth itself or roughly 12,451 miles. Looking at exhibit #1, you can easily see the representation of the wavelength.



(Exhibit #1 - Courtesy University of Arizona)

As you may already know, the tides themselves are divided into 2 types – spring tides, when the Earth, moon and sun align directly (higher highs, lower lows) and neap tides, when the Earth and moon are at right angles to the sun and cancel out some of the gravitational pulls of each other (lower highs, higher lows.)

As with most things, there is more than meets the eye or the sound-bite. Here is a not-so-widely known fact – the Earth gets a little closer (about 3%) to the sun during our northern hemisphere winter due to the natural shape of Earth's orbit around the sun. In fact, January is the month when we are at "perihelion" – closest to the sun – and thus when the sun's gravitational power is greatest.

Correspondingly, July is when Earth is at aphelion – farthest from the sun – and thus when the sun's gravitational power is least. Because the effect of gravity changes as a square of the distance, the ~3% change in distance effects the pull of gravity by about 10%. Further, as the Fates would have it, the moon also doesn't have a perfectly round orbit around the Earth. The moon's orbit is elliptical and it takes about 29 days to complete. The gravitational force is greatest when the moon is at "perigee" – closest to the Earth, resulting in the aforementioned spring tide and least powerful when it is at "apogee" – farthest from the Earth (about two weeks after perigee), resulting in the aforementioned neap tide.

So, what do you think happens when there is a spring tide during our winter, especially between December and February? You get "king tides", a term more commonly used in Pacific Rim countries than here. Of course, America has come to realize that it *is* a Pacific Rim country, so the term is gaining ground…

To round out the understanding of tides, it is important to note that while tides are ***largely*** about gravity, they aren't ***solely*** about gravity. Weather can have a localized effect on tides. High pressure systems can slow the tides from rising simply because the water has to lift something that weighs 14 pounds/square inch (the atmosphere) – except that it is heavier when we have a high pressure zone in play. In contrast, when we have a low pressure system at work, the opposite happens. The atmosphere just weighs less in a particular area. And do you know what we call a system of ***really*** low pressure?
A hurricane…

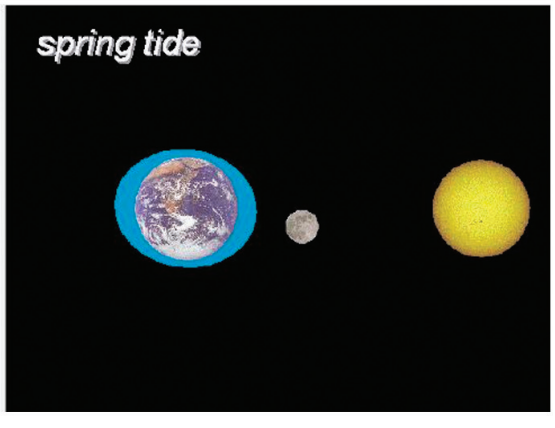


Exhibit #2 spring tides - Exhibit #3 neap tides, Courtesy University of Arizona.

The tides are rarely dangerous, except to the skipper who doesn't leave enough slack in his dock lines when making his boat fast to a fixed pier. But they are enormously powerful. How powerful? Over 80% of all the wave energy in the world is tied up in the tides. In fact, this energy and the friction related to it have actually lengthened the day on our planet. Over the past billion years, the day has lengthened from 19 hours to the present 24 hours.

What about what we called "tidal waves" as children – tsunamis? Traveling at speeds of 400 knots, tsunamis form in response to sudden changes in the shape and location of the sea floor, often due to landslides or earthquakes. Although devastating to affected areas, they are a small portion of the wave energy in the sea. Like any wave that breaks on the shore, these enormously high-speed waves pile up at the water's edge as all that energy compresses, much like a long line of train cars would pile up in an accident, rising up over itself and devastating all before it.

Wind DOES Create Waves

Jumping ahead since we lay the ground work back in September, take it as a given that the wind does create waves. And, on a windy but pleasant day, you can see the white caps marching in lock-step down the bays and in the offing to the ocean's horizon. But many mariners have experienced "confused seas," where the waves seem to come from everywhere; typically these are foul weather seas. What it going on? The wind seems to be coming from one direction – but the waves aren't. Why? This is due to the geometry of storms.

Most storms are low pressure systems with cyclonic winds orbiting the storm center. The cyclonic wind field creates waves moving in every direction. These newly formed waves tend to be steeper and more severe and have shorter periods than waves outside of a generation area. After wind waves form, their growth is limited by the duration of energy input. Energy input is determined by the velocity, duration, and fetch of the wind field. Waves reach an equilibrium state (the "fully developed sea") if all three of these variables remain constant for sufficient duration.

For higher velocities, these conditions are rarely realized because the waves tend to run out of the area with high winds. Even in a hurricane 300 miles across, a typical large wave will move out of the source area within half a day, far too little time to allow development of a "full sea."

So, there you have it. Wind creates waves – except for the longest wave, the tides, and the most destructive, the tsunami…

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